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(54) **An improved LED device for wide beam generation and method of making the same**

(57) A predetermined illuminated surface pattern is generated from a predetermined energy distribution pattern of an LED light source within an LED package having a light transmitting dome. An estimated optical transfer function of a lens shape of an optic is defined by the shape of an exterior and inner surface which envelopes at least in part the light transmitting dome of the LED package. An energy distribution pattern is obtained by

combination of the estimated optical transfer function and the predetermined energy distribution pattern of the light source. A projection of the energy distribution pattern onto the illuminated surface is determined. The projection is compared to the predetermined illuminated surface pattern. The estimated optical transfer function is then modified and the steps repeated until acceptable consistency is achieved between the projection and the predetermined illuminated surface pattern.

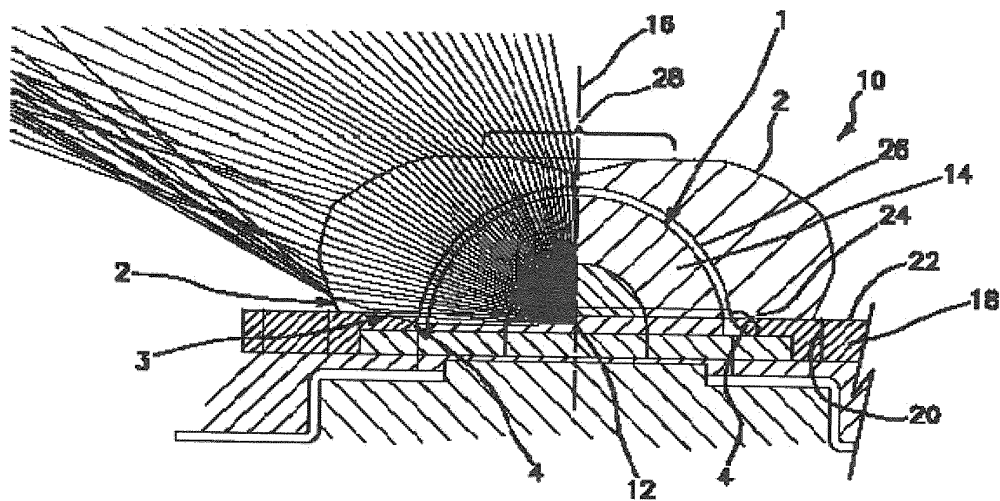


FIG. 1

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Description

[0001] Related Applications

[0002] The present application is related to U.S. Patent Application serial no. 11/711,218, filed on Feb. 26, 2007; U.S. Provisional Patent Application, serial no. 60/777,310, filed on Feb. 27, 2006; U.S. Provisional Patent Application, serial no. 60/838,035, filed on Aug. 15, 2006; U.S. Provisional Patent Application, serial no. 60/861,789, filed on Nov. 29, 2006; U.S. Provisional Patent Application, serial no. 60/939,275, filed on May 21, 2007, each of which are incorporated herein by reference and to which priority is claimed pursuant to 35 USC 119.

[0003] Background of the Invention

[0004] Field of the Invention

[0005] The invention relates to the field of apparatus and methods for using light emitting diodes (LEDs) or other light sources to generate predetermined wide profile two dimensional illumination patterns using a light source which has been optically modified to provide a corresponding wide profile beam or a flat array of multiple ones of such modified light sources.

[0006] Description of the Prior Art

[0007] The initial investment cost of LED illumination is expensive using cost per lumen as the metric when compared with traditional lighting means.

While this may change over time, this high cost places a premium on collection and distribution efficiency of the LED optical system. The more efficient the system, the better the cost-benefit comparison with traditional illumination means, such as incandescent, fluorescent and neon,

[0008] A traditional solution for generating broad beams with LEDs is to use one or more reflectors and/or lenses to collect and then spread the LED energy to a desired beam shape and to provide an angled array of such LEDs mounted on a curved fixture. For example, street light illumination patterns conventionally are defined into five categories, Types I - V. Type I is an oblong pattern on the street with the light over the center of the oblong. Type N is a symmetric four lobed pattern with the light over the center of the Sobed pattern. Type III is a flattened oblong pattern with the light near the flattened side of the oblong. Type IV is parabolic pattern with a flattened base with the light near the flattened base. Type V is a circular pattern with the light over the center of the circle. Any asymmetric aspect of these categorical patterns is obtained by mounting the light sources in a curved armature or fixture. By curving or angling the fixture to point the LEDs or light sources in the directions needed to create a broad or spread beam onto a surface, such as a street, a portion of the light is necessarily directed upward away from the street into the sky.

[0009] Hence, all airplane passengers are familiar with the view of a lighted city at night on approach. This often dazzling display is largely due to street lights and more particularly to street lights that have canted fixtures to create spread beams and hence collectively direct a sub-

stantial amount of light skyward. In an efficiently lighted city, the city would appear much darker to aircraft, because the street lights should be shining only onto the street and not into the sky. The dazzling city lights seen from aircraft and hill tops may be romantic, but represent huge energy losses, unnecessary fuel usage, and tons of unnecessary green house gas emissions from the electrical plants needed to generate the electricity for the wasted misdirected light.

[0010] Another technique is to use a collimating lens and/or reflector and a sheet optic such as manufactured by Physical Devices Corporation to spread the energy into a desired beam. A reflector has a predetermined surface loss based on the metalizing technique utilized. Lenses which are not coated with anti-reflective coatings also have surface losses associated with them. The sheet material from Physical Devices Corporation has about an 8% loss.

[0011] One example of prior art that comes close to a high efficiency system is the 'Side-emitter' device sold by Lumileds as part of their LED packaging offerings. However, the 'side-emitter' is intended to create a beam with an almost 90 degree radial pattern, not a forward beam. It has internal losses of an estimated 15% as well.

Another Lumileds LED, commonly called a low dome or bat wing LED, has a lens over the LED package to redirect the light, but it is to be noted that it has no undercut surface in the lens for redirecting the light from the LED which is in the peripheral forward solid angle. Similarly, it is to be noted that the conventional 5mm dome lens or packaging provided for LEDs lacks any undercut surface in the dome at all.

[0012] What is needed is an device that creates a wide angle beam, even the possibility of a radially asymmetric beam, that can be created with a design method that allows the designer to achieve a smooth beam profile which is not subject to the inherent disadvantages of the prior art.

[0013] Brief Summary of the Invention

[0014] The illustrated embodiment of the invention includes a method of providing a predetermined illuminated surface pattern from a predetermined energy distribution pattern of an LED light source within an LED package having a light transmitting dome. The method includes the steps of: defining an estimated optical transfer function for a lens shape of an optic having a potentially refracting exterior and inner surface enveloping at least in part the light transmitting dome of the LED package; generating an energy distribution pattern using the estimated optical transfer function of a lens shape given the predetermined energy distribution pattern of the light source; generating a projection of the energy distribution pattern onto the illuminated surface; comparing the projection of the energy distribution pattern to the predetermined illuminated surface pattern; modifying the estimated optical transfer function of the lens shape; and repeating the foregoing steps of generating the energy distribution pattern using the estimated optical transfer function of the

lens shape including the inner surface of the optic from the predetermined energy distribution pattern of the light source, generating the projection of the energy distribution pattern onto the illuminated surface, and comparing the projection of the energy distribution pattern to the predetermined illuminated surface pattern until acceptable consistency between the projection of the energy distribution pattern and the predetermined illuminated surface pattern is obtained. Then a lens is manufactured with the last obtained estimated optical transfer function including a shaped inner surface of the optic.

[0015] In the embodiment where the LED package is positioned within a well in a carrier, the step of defining an estimated optical transfer function of a lens shape of an optic includes the step of arranging and configuring the inner surface of the optic to direct light outside of the well, which light would otherwise be intercepted by the well but for its redirection.

[0016] In another embodiment the step of defining an estimated optical transfer function of a lens shape of an optic includes the step of arranging and configuring the inner surface of the optic to direct light in directions to satisfy user-defined system requirements.

[0017] While the apparatus and method has or will be described for the sake of grammatical fluidity with functional explanations, it is to be expressly understood that the claims, unless expressly formulated under 35 USC 112, are not to be construed as necessarily limited in any way by the construction of "means" or "steps" limitations, but are to be accorded the full scope of the meaning and equivalents of the definition provided by the claims under the judicial doctrine of equivalents, and in the case where the claims are expressly formulated under 35 USC 112 are to be accorded full statutory equivalents under 35 USC 112. The invention can be better visualized by turning now to the following drawings wherein like elements are referenced by like numerals.

[0018] Brief Description of the Drawings

[0019] Fig. 1 is the side cross sectional view of the illustrated embodiment.

[0020] The invention and its various embodiments can now be better understood by turning to the following detailed description of the preferred embodiments which are presented as illustrated examples of the invention defined in the claims. It is expressly understood that the invention as defined by the claims may be broader than the illustrated embodiments described below.

[0021] Detailed Description of the Preferred Embodiments

[0022] As a further improvement to a blob lens or optic, generally denoted by reference numeral 10 in Fig. 1, which is combined with an LED package 1 as described in the various incorporated applications referenced above, Fig. 1 is directed to still another embodiment which shows a radially symmetric blob optic 10 in side cross sectional view with a planar ray trace of an approximately Lambertian LED source 12. The dome 14 of the LED package 1 is shown as approximately hemispherical.

Dome 14 is disposed into a cavity defined in optic 10. There is an air gap or at least a zone 26 of contrasting index of refraction so that inner surface 4 of optic 10 is a potentially refracting surface which is radially positioned around dome 14. It is immaterial whether one looks at zone 26 as having the defining refracting surface or inner surface 4 of optic 10 as the defining surface, since it is the discontinuity in the index of refraction at their mutual boundary that defines the refracting surface. By modifying the interior surface 4 of the blob optic 10, the ray set from the LED source 12 can be modified to accommodate user-defined system requirements, which may vary from one specific application to another.

[0023] For example, in the illustration of Fig. 1 LED source 12 and package 1 is positioned in a well 20 defined in a carrier 18, which places LED source 12 below the level of upper surface 22 of carrier 18. Blob optic 10 is also shown as mounted into well 20 and extending below the level of surface 22.

[0024] Fig. 1 shows that a ray 3 from the LED source 12, which is radiated at 90 degrees from the vertical centerline 16 of LED source 12, would miss the outer surface 2 of the blob optic 10 and be lost or unavailable for useful application of any sort, if it were not redirected by the inner surface 4. This is of course true not only for ray 3, but all rays which ordinarily would lie in a lower peripheral solid angle of the forward hemispherical radiation pattern of LED package 1, which lower peripheral solid angle is intercepted by the interior walls of well 20 up to surface 22.

[0025] To avoid loss of this energy component from the output or beam formed by LED package 1 in combination with optic 10, the inner surface 4 of optic 10 is inwardly curved along its lower periphery or skirt 24 to create a refraction zone 26 between dome 14 and the inner surface of optic 10 that flares radially outward to refract the intercepted light from LED package 1 to a portion of the exterior surface 2 of optic 10, which is above the level of surface 22. In the illustrated embodiment the flared skirt 24 of surface 4 is azimuthally symmetric with respect to LED source 12. However, it is entirely within the scope of the invention that flared outward portion 24 may have a shape which is a function of the azimuthal angle.

[0026] Additional effects are contemplated by other shape modifications to the inside surface 4. For example, not only is the intercepted light from LED package 1 selected for redirection, any portion of the radiated light from LED package 1 may be optimally processed by a curved or shaped portion of inner surface 4 of optic 10 to redirect it to a selected portion of outer surface 2 of optic 10 for a user-defined system requirement as may be desired in any given application. For example, it is often the case that the light on or near axis 16 of LED package 1 is needed to be redirected to a different angle with respect to axis 16, namely out of the central beam toward the periphery or toward a selected peripheral direction. In such a case, inner surface 4 will then have an

altered shape in its upper crown region 28, adjacent or proximate to axis 16 to refract the central axis light from LED package 1 into the desired direction or directions. For example, inner surface 4 may be formed such that light incident on a portion of surface 4 lying on one side of an imaginary vertical plane including axis 16 is directed to the opposite side of the imaginary vertical plane or across optic 10.

[0027] It is to be expressly understood that the illustrated example of an additional optical effect is not limiting on the scope or spirit of the invention which contemplates all possible optical effects achievable from modification of inner surface 4 alone or in combination with correlated modifications of exterior surface 2 of optic 10.

[0028] In summary, the illustrated embodiment of the invention is a method of providing a predetermined illuminated surface pattern from a predetermined energy distribution pattern of an LED light source within an LED package having a light transmitting dome. The method comprises the steps of: defining an estimated optical transfer function of a lens shape of an optic having a potentially refracting outer and inner surface enveloping at least in part the light transmitting dome of the LED package; generating an energy distribution pattern using the estimated optical transfer function of a lens shape from the predetermined energy distribution pattern of the light source; generating a projection of the energy distribution pattern onto the illuminated surface; comparing the projection of the energy distribution pattern to the predetermined illuminated surface pattern, modifying the estimated optical transfer function of the lens shape; and repeating the steps of generating the energy distribution pattern using the estimated optical transfer function of the lens shape including the inner surface of the optic from the predetermined energy distribution pattern of the light source, generating the projection of the energy distribution pattern onto the illuminated surface, and comparing the projection of the energy distribution pattern to the predetermined illuminated surface pattern until acceptable consistency between the projection of the energy distribution pattern and the predetermined illuminated surface pattern is obtained.

[0029] The method further comprising manufacturing a lens with the last obtained estimated optical transfer function including a shaped inner surface of the optic. The method of manufacturing includes all modes of construction now known or later devised. For example, once the acceptable transfer function for the optic is determined according to the steps described above, the shape of the outer and inner surfaces of the optic is completely defined. The optic is typically molded from transparent or optical plastic or polymer.

[0030] In the illustrated embodiment the repeated steps generates a projection of the energy distribution pattern onto the illuminated surface which is compliant with a predetermined street light illumination pattern or more specifically, one of the Type I - V street light illumination patterns.

[0031] In most practical embodiments a plurality of LED light sources are combined, so that the steps of defining an estimated optical transfer function, generating an energy distribution pattern, generating a projection of the energy distribution pattern, comparing the projection of the energy distribution pattern, and modifying the estimated optical transfer function of the lens shape are repeated for each of the plurality of LED light sources.

[0032] Further in most practical embodiments the plurality of LED light sources are mounted in a fixture or in a carrier which is in turn mounted in the fixture. The steps of defining an estimated optical transfer function, generating an energy distribution pattern, generating a projection of the energy distribution pattern, comparing the projection of the energy distribution pattern, and modifying the estimated optical transfer function of the lens shape are repeated for each of the plurality of LED light sources taking into account a position and orientation for each of the LED light sources in the fixture or in the carrier in the fixture.

[0033] Typically, in many mountings the LED package is positioned within a well defined in a carrier so that the step of generating the energy distribution pattern using the estimated optical transfer function of a lens shape comprises generating an energy distribution pattern in which a portion of light is directed outside of the well without impingement of light from the LED light source onto the well, which portion of light is emitted from the LED light source into at least a portion of a forward hemispherical solid angle centered on the LED light source, which portion of light would otherwise impinge on some portion of the well but for its redirection. The step of directing a portion of the light outside of the well comprises directing the portion of the light outside of the well using an inwardly flared skirt on the inner surface of the optic.

[0034] In general, the step of generating the energy distribution pattern using the estimated optical transfer function of a lens shape comprises generating an energy distribution pattern in which light is directed in a pattern to satisfy in a user-defined system requirement.

[0035] In another embodiment the step of generating the energy distribution pattern using the estimated optical transfer function of a lens shape comprises generating an energy distribution pattern in which light is directed through the outer surface of the optic toward an opposing side of the optic from where the light is refracted by the outer surface.

[0036] In addition to the disclosed methods above, the illustrated embodiment expressly include the optic itself which is provided by these methods, or the fixture or carrier in which a plurality of such optics are included with their LED light sources.

Notwithstanding the claims, the invention is also described in the following clauses:

1. A method of providing a predetermined illuminated surface pattern from a predetermined energy distribution pattern of an LED light source within an LED

package having a light transmitting dome comprising: defining an estimated optical transfer function of a lens shape of an optic having a potentially refracting outer and inner surface enveloping at least in part the light transmitting dome of the LED package; generating an energy distribution pattern using the estimated optical transfer function of a lens shape from the predetermined energy distribution pattern of the light source; generating a projection of the energy distribution pattern onto the illuminated surface; comparing the projection of the energy distribution pattern to the predetermined illuminated surface pattern; modifying the estimated optical transfer function of the lens shape; and repeating the steps of generating the energy distribution pattern using the estimated optical transfer function of the lens shape including the inner surface of the optic from the predetermined energy distribution pattern of the light source, generating the projection of the energy distribution pattern onto the illuminated surface, and comparing the projection of the energy distribution pattern to the predetermined illuminated surface pattern until acceptable consistency between the projection of the energy distribution pattern and the predetermined illuminated surface pattern is obtained.

2. The method of clause 1 further comprising manufacturing a lens with the last obtained estimated optical transfer function including a shaped inner surface of the optic.

3. The method of clause 1 where the repeated steps generates a projection of the energy distribution pattern onto the illuminated surface which is compliant with a predetermined street light illumination pattern.

4. The method of clause 1 where the repeated steps generates a projection of the energy distribution pattern onto the illuminated surface which is compliant with one of the Type I - V street light illumination patterns.

5. The method of clause 1 where the LED light source is a plurality of LED light sources and where the steps of defining an estimated optical transfer function, generating an energy distribution pattern, generating a projection of the energy distribution pattern, comparing the projection of the energy distribution pattern, and modifying the estimated optical transfer function of the lens shape are repeated for each of the plurality of LED light sources.

6. The method of clause 1 where the LED light source is a plurality of LED light sources within a fixture, and where the steps of defining an estimated optical transfer function, generating an energy distribution pattern, generating a projection of the energy distribution

pattern, comparing the projection of the energy distribution pattern, and modifying the estimated optical transfer function of the lens shape are repeated for each of the plurality of LED light sources taking into account a position and orientation for each of the LED light sources in the fixture.

7. The method of clause 6 where the plurality of LED light sources are disposed in a carrier mounted in the fixture and where the steps of defining an estimated optical transfer function, generating an energy distribution pattern, generating a projection of the energy distribution pattern, comparing the projection of the energy distribution pattern, and modifying the estimated optical transfer function of the lens shape are repeated for each of the plurality of LED light sources taking into account a position and orientation for each of the LED light sources in the carrier in the fixture.

8. The method of clause 1 where the LED package is positioned within a well defined in a carrier and where generating the energy distribution pattern using the estimated optical transfer function of a lens shape comprises generating an energy distribution pattern in which a portion of light is directed outside of the well without impingement of light from the LED light source onto the well, which portion of light is emitted from the LED light source into at least a portion of a forward hemispherical solid angle centered on the LED light source, which portion of light would otherwise impinge on some portion of the well but for its redirection.

9. The method of clause 8 where directing a portion of the light outside of the well comprises directing the portion of the light outside of the well using an inwardly flared skirt on the inner surface of the optic.

10. The method of clause 1 where generating the energy distribution pattern using the estimated optical transfer function of a lens shape comprises generating an energy distribution pattern in which light is directed in a pattern to satisfy in a user-defined system requirement.

11. The method of clause 1 where generating the energy distribution pattern using the estimated optical transfer function of a lens shape comprises generating an energy distribution pattern in which light is directed through the outer surface of the optic toward an opposing side of the optic from where the light is refracted by the outer surface.

12. An optic for providing a predetermined illuminated surface pattern from a predetermined energy distribution pattern of an LED light source within an LED package having a light transmitting dome comprising

a potentially refracting outer and inner surface enveloping at least in part the light transmitting dome of the LED package, the outer and inner surfaces defining an estimated optical transfer function which when combined with the predetermined energy distribution pattern of an LED light source generates an energy distribution pattern, a projection of the energy distribution pattern onto the illuminated surface being derivable from the energy distribution pattern, wherein the outer and inner surfaces are defined by comparing the projection of the energy distribution pattern to the predetermined illuminated surface pattern; modifying the estimated optical transfer function of the outer and inner surfaces; and repeating the steps of generating the energy distribution pattern, generating the projection of the energy distribution pattern, and comparing the projection of the energy distribution pattern to the predetermined illuminated surface pattern until acceptable consistency between the projection of the energy distribution pattern and the predetermined illuminated surface pattern is obtained.

13. The optic of clause 12 where the outer and inner surfaces collectively provide a projection of the energy distribution pattern onto the illuminated surface which is compliant with a predetermined street light illumination pattern.

14. The optic of clause 12 where the outer and inner surfaces collectively provide a projection of the energy distribution pattern onto the illuminated surface which is compliant with one of the Type I - V street light illumination patterns.

15. The optic of clause 12 where the LED light source is a plurality of LED light sources each having a corresponding optic and where the outer and inner surfaces of the plurality of LED light sources collectively define an estimated optical transfer function, an energy distribution pattern, and a projection of the energy distribution pattern with acceptable consistency between the projection of the energy distribution pattern and the predetermined illuminated surface pattern.

16. The optic of clause 12 where the LED light source is a plurality of LED light sources each having a corresponding optic disposed within a fixture, and where the outer and inner surfaces of the plurality of LED light sources collectively define an estimated optical transfer function, an energy distribution pattern, and a projection of the energy distribution pattern with acceptable consistency between the projection of the energy distribution pattern and the predetermined illuminated surface pattern taking into account a position and orientation for each of the LED light sources in the fixture.

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17. The optic of clause 16 where the plurality of LED light sources are disposed in a carrier mounted in the fixture and where the outer and inner surfaces of the plurality of LED light sources collectively define an estimated optical transfer function, an energy distribution pattern, and a projection of the energy distribution pattern with acceptable consistency between the projection of the energy distribution pattern and the predetermined illuminated surface pattern taking into account a position and orientation for each of the LED light sources in the carrier in the fixture.

18. The optic of clause 12 where the LED package is positioned within a well defined in a carrier and where the outer and inner surfaces provide an energy distribution pattern in which a portion of light is directed outside of the well without impingement of light from the LED light source onto the well, which portion of light is emitted from the LED light source into at least a portion of a forward hemispherical solid angle centered on the LED light source, which portion of light would otherwise impinge on some portion of the well but for its redirection.

19. The optic of clause 18 where an inwardly flared skirt on the inner surface of the optic directs the portion of the light outside of the well.

20. The optic of clause 12 where the outer and inner surfaces generate an energy distribution pattern in which light is directed in a pattern to satisfy in a user-defined system requirement.

21. The optic of clause 12 where the outer and inner surfaces provide an energy distribution pattern in which light is directed through the outer surface of the optic toward an opposing side of the optic from where the light is refracted by the outer surface.

[0037] Many alterations and modifications may be made by those having ordinary skill in the art without departing from the spirit and scope of the invention. Therefore, it must be understood that the illustrated embodiment has been set forth only for the purposes of example and that it should not be taken as limiting the invention as defined by the following claims. For example, notwithstanding the fact that the elements of a claim are set forth below in a certain combination, it must be expressly understood that the invention includes other combinations of fewer, more or different elements, which are disclosed in above even when not initially claimed in such combinations.

[0038] The words used in this specification to describe the invention and its various embodiments are to be understood not only in the sense of their commonly defined meanings, but to include by special definition in this specification structure, material or acts beyond the scope of

the commonly defined meanings. Thus if an element can be understood in the context of this specification as including more than one meaning, then its use in a claim must be understood as being generic to all possible meanings supported by the specification and by the word itself.

[0039] The definitions of the words or elements of the following claims are, therefore, defined in this specification to include not only the combination of elements which are literally set forth, but all equivalent structure, material or acts for performing substantially the same function in substantially the same way to obtain substantially the same result. In this sense it is therefore contemplated that an equivalent substitution of two or more elements may be made for any one of the elements in the claims below or that a single element may be substituted for two or more elements in a claim. Although elements may be described above as acting in certain combinations and even initially claimed as such, it is to be expressly understood that one or more elements from a claimed combination can in some cases be excised from the combination and that the claimed combination may be directed to a subcombination or variation of a subcombination.

[0040] Insubstantial changes from the claimed subject matter as viewed by a person with ordinary skill in the art, now known or later devised, are expressly contemplated as being equivalent within the scope of the claims. Therefore, obvious substitutions now or later known to one with ordinary skill in the art are defined to be within the scope of the defined elements.

[0041] The claims are thus to be understood to include what is specifically illustrated and described above, what is conceptionally equivalent, what can be obviously substituted and also what essentially incorporates the essential idea of the invention.

Claims

1. A lighting system (10) comprising:
 - a carrier (18);
 - a light emitting diode package (1) positioned at the carrier, and
 - an optic (10) comprising an exterior surface (2) and an interior surface (4), wherein the interior surface defines a cavity, wherein a portion (24) of the interior surface has a shape that is a function of azimuthal angle with respect to the light emitting diode source, as distinct from azimuthally symmetric.
2. The lighting system of claim 1 further comprising a light transmitting dome (14) disposed on a light emitting diode source (12).
3. Lighting system according to claim 2 in which the dome is disposed at least in part in the cavity.
4. Lighting system according to claims 2 or 3 further comprising an air gap disposed between the dome and the interior surface.
5. The lighting system of claim 4 wherein the light emitting diode package, the optic, and the air gap comprise a light source, wherein the light source and a plurality of other light sources are attached to the carrier, wherein the lighting system further comprises a fixture in which the carrier is mounted, and wherein the lighting system provides a predetermined street light illumination pattern.
6. The lighting system of any of the preceding claims wherein the light emitting diode package has an axis (16), wherein an imaginary vertical plane includes the axis, and wherein the interior surface is formed such that light incident on an area of the interior surface lying on one side of the imaginary vertical plane is directed to an opposite side of the imaginary vertical plane.
7. The lighting system of any of the preceding claims wherein the interior surface is formed such that light incident on an area of the interior surface is directed across the optic.
8. The lighting system of any of the preceding claims wherein the interior surface comprises an upper crown region (28), and wherein the interior surface has an altered shape in the upper crown region to refract central axis light into a desired direction or directions.
9. The lighting system of any of the claims 6-8, wherein the interior surface has an altered shape adjacent or proximate to the axis to refract central axis light from the light emitting diode package into a desired direction or directions.
10. The lighting system of any of the preceding claims wherein the optic comprises a flared skirt (24).
11. The lighting system of any of the preceding claims wherein light is directed through the exterior surface of the optic toward an opposing side of the optic from where the light is refracted by the exterior surface.
12. The lighting system of any of the preceding claims 4-11, wherein a light source comprises the light emitting diode package, the optic, and the air gap, and wherein the light source is one of a plurality of light sources within a fixture.
13. The lighting system of any of the preceding claims wherein the optic produces a radially asymmetric beam from light emitted by the light transmitting dome.

14. The lighting system of any of the preceding claims wherein the exterior surface is radially symmetric.
15. The lighting system of any of the preceding claims wherein the outer surface comprises a refracting outer surface. 5
16. The lighting system of any of the preceding claims wherein the inner surface comprises a refracting inner surface. 10
17. The lighting system of any of the preceding claims wherein the lighting system comprises a street light.
18. The lighting system of any of the preceding claims wherein the optic is configured to produce a radially asymmetric wide angle beam achieving a smooth beam profile. 15

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EUROPEAN SEARCH REPORT

Application Number
EP 13 16 0382

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 5 924 788 A (PARKYN JR WILLIAM A [US]) 20 July 1999 (1999-07-20) * columns 1,2,5,6 - column 7; figures 4,5,6,7,9,10 *	1-18	INV. B60Q1/26 G02B17/08 F21V5/04 G02B27/09 G02B17/00
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 29 April 2013	Examiner Feeney, Orla
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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EPO FORM 1503 03.02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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